Uranium Content Measurement of Some Soil Samples in North of Nineveh Province

Malik H. Kheder
Hanaa N. Azeez
Physics Department, Education College, University of Al-Hamdaniya, Mosul - Iraq.

Abstract

Assessment of natural radiation exposure, by Inspection radioactivity level from radionuclides in the soil, is very important to be their quantity under control. Depending on geological locations, uranium varies widely in soil (from 0.1 to 20 ppm). Sixteen samples of soil collected from different locations in the north of Nineveh province-Iraq and the level of uranium measured using a CR-39 nuclear track detector. Uranium concentrations vary (from 0.393 to 0.867) ppm and mean value is 0.592 ppm. Uranium specific activity from 4.866 to 10.716 Bq kg^{-1} the mean value 7.317 Bq kg^{-1}. Results compared with average values worldwide in general, values found lower than of permissible limit worldwide uranium concentration value of 11.7 ppm, and uranium specific activity value of 35 Bq/Kg.

Keywords: CR-39 detector, uranium concentration, uranium activity, soil, Nineveh province.

قياس نسبة اليورانيوم في بعض عينات التربة في شمال محافظة نينوى

مالك حسين خضر

هناء نافع عزيز

قسم الفيزياء، كلية التربية، جامعة الحمدانية، موصل – العراق.

المستخلص

تقييم التعرض للإشعاع الطبيعي من خلال فحص مستوى النشاط الإشعاعي من النوى المشعة في التربة مهم جداً للتحكم في كميتها. اعتماداً على المواقع الجيولوجية، يتنوع اليورانيوم بشكل كبير في التربة (من ٠,١ إلى ٢٠ جزء في المليون) ppm. تم جمع ستة عشر عينة من التربة من مواقع مختلفة في شمال محافظة نينوى – العراق وتم قياس مستوى اليورانيوم باستخدام كاشف الاثر النووي CR-39. تختلف تراكيز اليورانيوم (من ٠,٣٩٣ إلى ٠,٨٦٧) ppm جزء في المليون ومتوسط القيمة ppm ٠,٥٩٢ جزء في المليون. الفعالية النوعية لليورانيوم من (٤,٨٦٦ إلى ١٠,٧١ Bq/kg) متوسط القيمة ٧,٣١٧ Bq/kg. وبمقارنة النتائج مع متوسط القيم في جميع أنحاء العالم بشكل عام، وجدت القيم أقل من الحد المسموح به في جميع أنحاء العالم لتركيز اليورانيوم بقيمة ١١,٧ ppm، وقيمة النشاط النوعي لليورانيوم ٣٥ Bq/kg.

الكلمات المفتاحية: تركيز اليورانيوم، فعالية اليورانيوم، التربة، محافظة نينوى، كاشف CR-39.

Introduction

Soil natural radioactivity is considered as a basic indicator for radiological contamination since it is a major source for natural radioactivity because of the mineral content, and it is the source for the radiation-hazard for the population and a source for transfer of radionuclides into the environment[1]. The main determinations of the natural background radiation are the soil radionuclide concentration[2]. From one type of soil to another, the natural radioactivity may vary considerably. Radionuclides are found in the soil and environment, as NORMs elements naturally occurring, which is terrestrial background radiation the emitted nuclear-radiations from naturally occurring radionuclides materials, and as nuclear technologies product, uranium one of these radionuclides[3]. Uranium like many other minerals is an element naturally occurring has always present, since the earth's formation. Since all uranium isotopes are radioactive, therefore there quantity is must be under control[4]. It decays by emitting alpha particles, becoming a non-radioactive lead. New radionuclide along the chain of decay is called a progeny (or decay product), each one contributes more than uranium itself about seven times to the total soil radioactivity. Uranium is the radium and radon proximate source in the rocks and soil. One of the background radiation largest contributors is radon a progeny of uranium[5]. High uranium intake and products of its decay lead to human being's harmful effects. Kidneys chemical damage transient result by exposure to a bodyweight of 0.1 $mg.Kg^{-1}$ natural uranium soluble[6]. Depending on geological locations, uranium in the soil varies widely (from 0.1 to 20 ppm), the average value of the world is 2.8 $mg.\ Kg^{-1}$ (specific activity 35 Bq/Kg)[7], and the allowed limit 11.7 ppm[8][9].

CR-39 (The plastic SSNTD) detector used to find the uranium specific activity in the soil and concentration of uranium. Because of CR-39 high sensitivity to low energy alpha particles. These tracks are observed by microscope after enlargement by etching process[10].

The research aimed to determine specific uranium activity and concentrations of uranium in sixteen samples of soil from the north of Nineveh province-Iraq. The measurement of uranium concentration is necessary to investigate the concentration in causing cancer and various diseases.

MATERIALS AND METHODS

Sixteen soil samples from different locations were collected in the north of Nineveh province-Iraq. Samples were taken from a 35 cm depth. The samples sieved with a mesh of 0.2 mm, then dried at 100 C^o in the oven for 24 hours. Samples were then filled in a container (uranium dosimeter), which were with plastic tape sealed to prevent the airborne radionuclides escape. Uranium dosimeter with nuclear used, the measurements made solid-state track detector techniques. **Figure 1**.

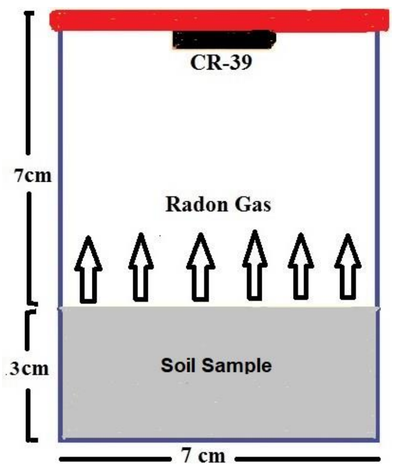

Figure (1)
Uranium dosimeter technique of the sealed-can

Each container cup height is 10 cm and a diameter of 7 cm contains (1 x 1) cm^2 of CR-39 detector. With adhesive tape double-sided fixed to the bottom of the cup cover. Alpha particles leave tracks when reaching the detector. The track's number is proportional to the radon average concentration. Each sample of 170 gm placed inside a cylindrical container of plastic (uranium dosimeter) facing to CR-39 detector. The distance between detectors to the sample surfaces is 7 cm and the height of the sample is 3 cm. Closed for 60 days (2 Dec 2020 - 1 Feb 2021). After 60 days, detectors removed then by NaOH etched at 6.25 N normality in water bath heat 70 C^o to the tracks reveal. Detectors washed, with a microscope track counted at 400x magnification.

Track densities are measured by the following relation [11].

$$Track\ density\ \rho = \frac{Total\ number\ of\ tracks}{Area\ of\ the\ field\ of\ view} \quad (1)$$

In sample air space radon concentration C_{Rn}(Bq/m^3) related to exposure time T(in a day) the track density ρ(in track/cm^2) by the equation [12].

$$\rho = KC_{Rn}T \quad (2)$$

Where K (track/m^2) is the sensitivity defined by track density per exposure unit (Bq.s/m^3). K is given in units of track/cm^2 per Bq.d/m^3 (divided by 8.64 for convert to m), where T in units of [day] is the exposure time.[13]
K calculated from formula.[14]

$$K = \frac{1}{4} r \left(2cos\theta_c - \frac{r}{R_i}\right) \quad (3)$$

Where θ_c is the CR-39 detector critical angle equals 35^o, R_i

is the alpha particle range in air 4.09 cm (for an emitted alpha particle with energy 5.49 MeV from radon), r is the sealed can radius (3.5 cm)[15]. Calculated by the equation.

$$R_i = 0.318\ E_i^{3/2} \qquad (4)$$

K then equal (0.684 cm) by multiplying with 0.0864 its value become (0.0591 Traks.cm^{-2}.day^{-1}/Bq.m^{-3})[16].

Radon concentration Rn in the sample is calculated by the equation [17].

$$C_s = \lambda_{Rn}\ C_{Rn}\ H\ T/L \qquad (5)$$

Where Radon concentration C_s (Bq/m^3) in the sample, C_{Rn} Radon concentration in the sample air space (Bq / m^3), λ_{Rn} (0.1814 day^{-1}) decay constant of radon, H (7cm) the air space height in the can, T (60 days) the exposure time, L (3cm) the sample thickness.

The radon activity (A_{Rn}) in the sample was determined from relation.

$$A_{Rn} = C_s\ V \qquad (6)$$

Where A_{Rn} is radon activity in the sample, the sample volume is $(V = \pi r^2 L)$ = 115.4 X 10^{-6} m^3, r is the can radius[18].

Uranium concentration is determined from the radon activity by the number of radon atoms N_{Rn} by the relation[19].

$$A_{Rn} = \lambda_{Rn}\ N_{Rn} \qquad (7)$$

Using the secular equilibrium equation (the uranium activity equal to radon activity) the number of uranium atoms N_U in the sample can be determined.

$$\lambda_U N_U = \lambda_{Rn} N_{Rn} \quad (8)$$

Where λ_U (4.883 X 10^{-18} sec^{-1}) is uranium decay constant, and then the uranium weight in the sample is calculated by the equation[20].

$$W_U = N_U At_U / N_{avo.} \quad (9)$$

Where At_U is the mass number of uranium ^{238}U, $N_{avo.}$ (6.02 X 10^{23} atom / mol) is the Avogadro number?

Uranium concentration is calculated from equation[21].

$$C_U = W_U / W_s \quad (10)$$

Where C_U (ppm) is the uranium concentration, W_s (170 gm) is the sample mass.

The uranium activity concentration in units (Bq.Kg^{-1}) calculated using the equation. [22].

$$Ac_U = \lambda_U N_{avo.} [At_U]^{-1} C_U \quad (11)$$

Where C_U must be in units of (g/Kg) (since 1ppm=10^{-6}g/g = 10^{-3}g/Kg).

RESULTS AND DISCUSSION

Results of the uranium concentrations found to vary between (0.393-0.867) ppm with the mean value of 0.592 ppm, Uranium specific activity ranged from 4.866 to 10.716 Bq kg^{-1} with a mean value of 7.317 Bq kg^{-1}. The calculated values for radon concentration in soil samples are in the range (5840.3-14608.5) Bq/m^3 with a mean value of 9104.52 Bq/m^3in the investigated sixteen samples presented in Table 1, and shown as barcodes in figures 2. the minimum value observed for Uranium specific activity was in sample S16 (4.866 Bq kg^{-1}) and the maximum value was for the sample S6 (10.716 Bq kg^{-1}), with the average value of 7.317 Bq kg^{-1} all measured values are less than world average value of uranium specific activity 35 Bq/Kg. For uranium concentrations, the minimum was 0.393 ppm (Sample S16) and the maximum was 0.867 ppm (Sample S6) with an average of 0.592 ppm less than the worldwide value of 11.7 ppm.

The results displayed in Table 2 shows that the obtained values fall within the corresponding some values published for other locations in Iraq. Where it is within the other measurements in AL-Hamdaniya-Mosul and Jalawla'a city-Diyala regions, greater four times than Al-Najaf region, too much less than Sulaimani region. The concentrations reported on dry soil samples, the origin of soil types, and geochemical composition attribute to rising the recorded radionuclides values in the soil sample of the particular area, and may be due to the radioactive rich sandstone presence. Hence It concluded that there are no harmful effects of radiation posed to the population in the study area, safe as for as radiological risks and health hazards due to concentration of uranium in the soil.

Table (1)
Results of the track density, radon concentration in soil, uranium weight in the sample, uranium concentration, and uranium specific activity in soil samples

S.	ρ Track / cm^2	C_S Bq/m^3	W_U X10^{-6} gm	C_U ppm	Ac_U Bq/Kg
S1	1700	12195.81	113.946	0.670	8.280
S2	1140	8178.37	76.411	0.449	5.553
S3	1800	12913.22	120.649	0.709	8.767
S4	1680	12052.33	112.605	0.662	8.183
S5	1240	8895.77	83.113	0.489	6.040
S6	2200	15782.82	147.460	0.867	10.716
S7	1820	13056.70	121.989	0.717	8.865
S8	1999	14340.84	133.987	0.788	9.737
S9	1300	9326.214	87.135	0.512	6.332
S10	1440	10330.57	96.519	0.567	7.014
S11	1360	9756.655	91.157	0.536	6.624
S12	1400	10043.61	93.838	0.552	6.819
S13	1200	8608.813	80.432	0.473	5.845
S14	1340	9613.175	89.816	0.528	6.527
S15	1419	10179.92	95.111	0.559	6.912
S16	999	7166.837	66.960	0.393	4.866
Min	**999**	**7166.837**	**66.960**	**0.393**	**4.866**
Max	**2200**	**15782.82**	**147.460**	**0.867**	**10.716**
Mean	**1502.31**	**10777.6**	**100.696**	**0.592**	**7.317**

Table (2)
Compression with recent measurements in Iraq

N	Research	Location	Uranium concentration (*ppm*)		
			Min	Max	Mean
1.	Present work	North of Mosul province - Iraq	0.393	0.867	0.592
2.	2013 ref.[23]	Jalawla'a city-Diyala-Iraq	0.719	1.280	_____
3.	2014 ref.[24]	Al-Najaf - Iraq	0.093558	0.184325	_____
4.	2015 ref.[25]	Sulaimani - Iraq	1.253	18.225	6.029
6.	2017 ref.[26]	AL-Hamdaniya-Mosul-Iraq	0.313	0.784	0.488

Figure (2): The variation of the values of the uranium specific activity concentration in the samples, it varies depending to uranium content from one sample to another.

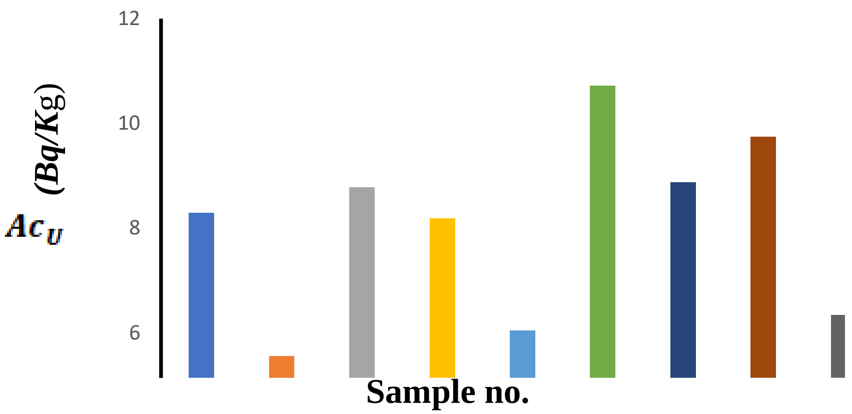

Figure (2)
Uranium specific activity (*Bq/Kg*) in samples

CONCLUSIONS

Most of the uranium specific activity result values of this investigation showed the low presence of uranium in soil samples were lower than the world average values. The obtained values of uranium specific activity less than the world average value 35 Bq/Kg, and uranium concentration, found to be less than the maximum permissible limit 11.7 ppm and worldwide average value 2.8 ppm as recommended by UNSCEAR. Hence It concluded that there are no harmful effects of radiation posed to the population in the study area, safe as for as radiological risks and health hazards due to concentration of uranium in the soil.

References

[1] Rahman S. and Faheem M., (2008), "Natural radioactivity measurements in Pakistan-an overview," *J. Radiol. Prot.*, vol. 28, no. 4, p. 443.

[2] Taskin H., Karavus M., Ay P., Topuzoglu A., Hidiroglu S., and Karahan G., (2009), "Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey," *J. Environ. Radioact.*, vol. 100, no. 1, pp. 49–53.

[3] White R. E., (2013), *Principles and practice of soil science: the soil as a natural resource*. John Wiley & Sons.

[4] Graetz G., (2015), "Energy for whom? Uranium mining, Indigenous people, and navigating risk and rights in Australia," *Energy Res. Soc. Sci.*, vol. 8, pp. 113–126.

[5] Todorov P. T. and Ilieva E. N.,(2005), "Contamination with uranium from natural and anthropological sources," *Rom. J. Phys.*, vol. 50, no. 9–10, pp. 25–30.

[6] Tanner A. B., (1980), "Radon migration in the ground: a supplementary review".

[7] Sahoo S. K., (2009), "Measurement of uranium and its isotopes at trace levels in environmental samples using mass spectrometry," *Indian J. Phys.*, vol. 83, no. 6, pp. 787–797.

[8] Saied B. M., Al-Khafaji R. M., and Al-Bayati A. T., (2016) "Measurement of Uranium Concentration in the Soil Samples by Using Solid State Nuclear Track Detectors (SSNTDs)," *Int. J. Sci. Res. Sci. Technol.*, vol. 2, no. 4, pp. 130–135.

[9] UNSCEAR, (2000), "United Nations Scientific Committee on the Effects of Atomic Radiation," *Sources and effects of ionizing radiation*, vol. 2. United Nations New York.

[10] Fleischer R. L., Price P. B., and Walker R. M., (1975), *Nuclear tracks in solids: principles and applications*. Univ of California Press.

[11] Kheder M. H., (2019), “Measurement of radon concentration using SSNTD in Bartella region,” *Al-Mustansiriyah J. Sci.*, vol. 29, no. 4, pp. 110–116.

[12] Ahmad N., Jaafar M. S., Khan S. A., Nasir T., Ahmad S., and Rahim M., (2014), “Measurement of radon exhalation rate, radium activity and annual effective dose from bricks and cement samples collected from Dera Ismail Khan,” *Am. J. Appl. Sci.*, vol. 11, no. 2, p. 240.

[13] Nikezic D., Yu K. N., and Stajic J. M., (2014), “Computer program for the sensitivity calculation of a CR-39 detector in a diffusion chamber for radon measurements,” *Rev. Sci. Instrum.*, vol. 85, no. 2, p. 22102.

[14] Kheder M. H., Azeez H. N., and Al-Jomaily F. M., (2020), “Alpha Emitters Radioactivity Concentrations in Some Cosmetics Used in Iraq Using LR-115 Detector,” *EUREKA Phys. Eng.*, no. 2, pp. 65–70.

[15] Mansy M., Sharaf M. A., Eissa H. M., El-Kamees S. U., and Abo-Elmagd M., (2006), “Theoretical calculation of SSNTD response for radon measurements and optimum diffusion chambers dimensions,” *Radiat. Meas.*, vol. 41, no. 2, pp. 222–228.

[16] Kheder M. H., Najam L. A., Mahmood R. H., and Majeed F. A., (2020), “Radioactivity concentrations in barley and wheat crops in Nineveh plain region in Iraq,” *Int. J. Nucl. Energy Sci. Technol.*, vol. 14, no. 1, pp. 50–60.

[17] Somogyi G., Hafez A. F., Hunyadi I., and Toth-Szilagyi M., (1986), “Measurement of exhalation and diffusion parameters of radon in solids by plastic track detectors,” *Int. J. Radiat. Appl. Instrumentation. Part D. Nucl. Tracks Radiat. Meas.*, vol. 12, no. 1–6, pp. 701–704.

[18] Kheder M. H., Ahmad A. M., Azeez H. N., and Mustafa I. F., (2019), “Radium and Uranium Concentrations of Powder Juice in the Iraq Markets Using CR-39 Detector,” *J. Univ.*

Babylon Pure Appl. Sci., pp. 341–349.

[19] L'Annunziata M. F., (2016), *Radioactivity: introduction and history, from the quantum to quarks*. Elsevier.

[20] Podgorsak E. B., (2005), "Basic radiation physics," *Radiat. Oncol. Phys. a Handb. Teach. students. Vienna IAEA*, vol. 7.

[21] Kheder M. H., Najam L. A., and Azeez H. N., (2020), "Long-lived alpha emitters concentrations in the spices consumed in Iraq using CR-39 detector," *J. Univ. Babylon Pure Appl. Sci.*, pp. 274–283.

[22] Kheder M. H., Ahmad A. M., Azeez H. N., Slewa M. Y., Badr B. A., and Sleeman S. Y., (2019), "Radon and uranium concentration in ground water of nineveh plain region in iraq," in *Journal of Physics: Conference Series*, vol. 1234, no. 1.

[23] Mohammad A. M., Ahmed I. k, and Ahmed Y. S., (2013), "Measurement of Uranium Concentration in Some Soil Samples in Jalawla'a City Using CR-39 Detector," *Al-Nahrain J. Sci.*, vol. 16, no. 1, pp. 112–116.

[24] Abojassim A. A., (2014), "Uranium concentrations measurement for groundwater and soil samples in Al-Najaf/Iraq," *IOSR J. Appl. Chem.*, vol. 6, no. 5, pp. 61–65.

[25] Abdullah K. O., Muhammed S. Z., and Hussein A. M., (2015), "Assessment of Rn and U concentrations in the soil of Qadafery, Kalar and Zarayan located in Sulaimani governorate of Kurdistan region-Iraq," *Am. J. Environ. Prot.*, vol. 4, no. 1, pp. 40–44.

[26] Kheder M. H., Azeez H. N., Slewa M. Y., and Zaker T. A., (2019), "Determination of Uranium Contents in Soil Samples in Al-Hamdaniya Region Using Solid State Nuclear Track Detector CR-39," *Al-Mustansiriyah J. Sci.*, vol. 30, no. 1, pp. 199–204.